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CONTEMPORARY ECONOMIC POLICY

AN EXAMINATION OF THE EFFECTS OF ENVIRONMENTAL REGULATIONS ON RETAIL GASOLINE PRICE SEASONALITY

MICHAEL C. DAVIS

Stricter environmental standards on gasoline have had impacts on the prices of gasoline including the seasonality of gasoline prices. Using both national data and individual station data, the paper tests for a possible explanation for this increase. Three theories are tested: that gasoline seasonality increases due to higher costs, due to greater market power because of segmented markets, or due to greater asymmetry because of greater inattention on the part of customers. The results suggest that gasoline price seasonality has increased both due to higher costs and greater market power with mixed results on the inattention of consumers. (*JEL* Q41, Q53, Q58).

I. INTRODUCTION

An issue of particular importance to researchers and policymakers in the current century has been the rise in gasoline prices. In addition to prices rising sharply beginning in 2005, there has also been a dramatic rise in the seasonal variation of prices which has been much more acute since 2000. Figure 1 shows the difference between the national average June and January gasoline prices. From 1983 to 1999 there was variation from year to year, but the difference hovered around 10 cents. Between 2000 and 2013, there was a sharp increase in the difference, regularly being over 20 cents.

We examine one specific suspect for the cause of this increase, the Reformulated Gasoline Program (RFG). In 2000, Phase II of the RFG program went into effect. This regulation placed more stringent environmental requirements on gasoline. In particular, these requirements are more stringent during the summer than the winter.

Studies looking at gasoline price seasonality prior to 2000 find little evidence in support of seasonality. Davis and Hamilton (2004) find no evidence in support of seasonality, and Chouinard and Perloff (2007) find statistically significant but small evidence of seasonality. Davis (2009) examines seasonal adjustment of monthly average retail prices and finds that there is substantially more variation in prices since 2000 than before. However, because of the lack of data available, as the post 2000 sample only included up to 2004, he does not find that the monthly dummy variables are significantly different from zero.

In addition to Davis's (2009) examination of the seasonal components associated with the RFG program, other studies have found price effects of the RFG program. Bulow et al. (2003) showed that the initiation of the RFG program was partially responsible for the price spikes that happened in the Midwest in 2000. Muehlegger (2006) found that the RFG program caused larger price spikes in Wisconsin, Illinois, and California, while Chakravorty, Nauges, and Thomas (2008) found that wholesale prices increased in response to the RFG program.

An additional concern associated with the RFG program is that many states imposed their own specific requirements on gasoline prices. Walls and Rusco (2007) found that areas with the most unique requirements typically have the highest prices. Auffhammer and Kellogg (2011)

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ABBREVIATIONS

ECM: Error-Correction Model
EIA: Energy Information Agency
OPIS: Oil Price Information Services
OXY: Oxygenated Gasoline
RFG: Reformulated Gasoline Program

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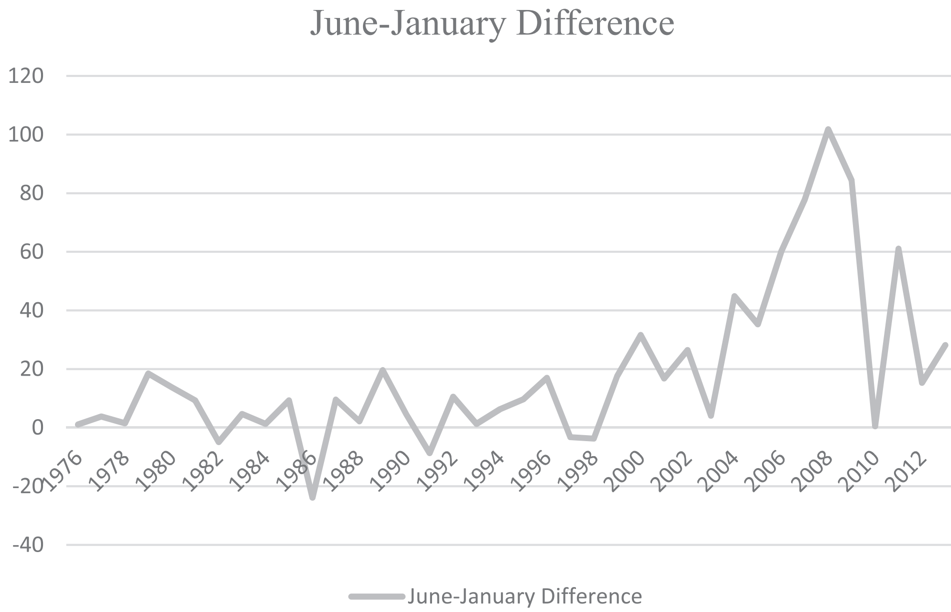
FIGURE 1
June January Gasoline Price Difference (1976–2013)



Data: Energy Information Agency

found that while costs are higher with the various state standards that the specific strict standards of California had a positive impact on ozone gas reduction, while federal standards had very little impact.

The finding of increased seasonality is important for researchers. In previous work the presence of seasonality was found not to exist or to be negligible, so researchers could ignore the implications of it. But in data from recent years, the seasonal variation is large enough that ignoring it when examining gasoline prices will likely cause error in their work.

Seasonality is also important for public policy decisions. It may be the case that there are very good environmental reasons for different standards during the summer and winter. As shown by Auffhammer and Kellogg (2011) there may also be good reasons for geographical variations in the strictness of the policies. However, if there are not good reasons, perhaps these programs should be changed so that they are more efficient. Also policy changes based on high gasoline prices should not be made because of short term fluctuations in June which will be corrected in October. Policymakers need to be aware of the seasonal pattern so that they do not make misguided short term corrections with long term impacts.

This study conducts two empirical analyses to examine whether the seasonality changed and whether the RFG program is responsible. The first analysis is to re-estimate the Davis (2009) study using national data and an error-correction model (ECM). The main limitation of the Davis study was the availability of the data only up to 2004, whereas this study updates the data to 2013. The second study is to investigate retail gasoline stations in six zip codes across the United States. This data allows us to test for differences in responses across areas under different regulatory conditions.

II. RFG PROGRAM

The 1990 Clean Air Act includes provisions for emission standards for motor gasoline. One of these programs is the RFG program. The RFG program is designed to reduce smog as well as toxic chemicals from gasoline emissions. Phase I of the program went into effect in December of

1994. The EPA estimates that Phase I has reduced emissions of the chemicals leading to smog by 17% and toxic pollutants by 22% (Environmental Protection Agency 1999a). Phase II of the RFG program went into place in January 2000 and placed even more stringent standards in order to reduce both smog and toxic emissions even more.

Phase II of the RFG program made stricter the emissions standards with regards to three pollutants: Toxic Air Pollutants, Volatile Organic Compounds, and Nitrogen Oxides. Of these, only the requirements for Toxic Air Pollutants became more stringent year round. For the other two pollutants, the requirements placed much more stringent requirements during the summer. Since the requirements are much more stringent in the summer than winter, we expect an increase in seasonality in gasoline prices. For more information on the environmental impact of the RFG program, see the United States Environmental Protection Agency (1999a, 1999b) and Linderdale and Bohn (1999).

Linderdale and Bohn (1999) estimate that Phase II of the RFG program would add 2.5 cents per gallon in RFG areas in the winter, 4 cents in the RFG Northern areas in the summer and 3.5 cents in RFG Southern states in the summer. These estimates suggest an increase in seasonality of 1 or 1.5 cents per gallon for areas under the RFG program and no suggestion of increased prices in non-RFG areas. So while these effects are predictable, the increase in seasonality is much greater than the a priori estimates.

There are a few reasons why we might see higher seasonality in fuel prices since the imposition of stricter standards. First, the gasoline under the stricter standard would be more expensive to produce. Some of that increase in costs would naturally be passed on to the consumer in the form of higher prices. The firms can achieve the higher environmental standards by mixing their gasoline with either ethanol or MTBE. At the same time the RFG standards were being put in place, and for the following years, many states started putting in place bans on MTBE. The increased usage of ethanol would exacerbate the cost impacts of the standards as the ethanol is more expensive (Anderson and Elzinga 2014). One impact demonstrating the degree of importance of this change is the finding of Tenkorang et al. (2015) that the increased use of ethanol in blending has led to ethanol and gasoline being complements as opposed to the substitutes they used to be. Also, the RFG fuel seems to get lower gas mileage (Linderdale and Bohn 1999). The lower gas mileage would increase demand, at least partially, leading to higher prices. It is not clear however that this effect has a seasonal component, as it might just be result of the RFG gasoline and not specifically the RFG summer or winter gasoline.

A second scenario is that the different standards could lead to greater market power for the gasoline producers (Brown et al., 2008; Chakravorty, Nauges, and Thomas 2008; Walls and Rusco 2007). The different types of gasoline required for different areas could cause the individual markets for each gasoline type to be small. This problem is exacerbated by the extensive and differing state and local regulations. There are extensive economies of scale in gasoline production, making it very difficult to produce a small amount of gasoline of a particular type. Combining these two issues suggests that when the regulations are in place there should be an increase in price.

A third theory is that there could also be switch over costs associated with producing gasoline. We might see jumps in the price in March/April and August/September as they switch from winter gasoline to summer gasoline and back again. During these months, many firms run down inventories to make way for the other type of gasoline (Bulow et al. 2003).

Most of the above reasons specifically relate to price changes at the refined or wholesale (or rack) level. When examining retail data, we should expect most of the price effect to be passed through from the wholesale price to the consumers. However, an additional effect at the retail level could be that firms are less likely to change their prices. In particular, they may start to exhibit a more pronounced asymmetric pattern to their prices.

There are a number of reasons we might see an increased asymmetry in gasoline prices from the RFG program. Borenstein, Cameron, and Gilbert (1997) suggest that an increase in asymmetry may be caused by inventory constraints. When faced with a downward shock, the firms simply keep prices the same and sell less, but when faced with an upward shock they must react immediately and possibly run out of gasoline. The requirements on selling particular fuels at certain times of year may lead firms to optimally keep lower inventories, exacerbating the inventory constraint. If the higher input prices drive retailers out of the market, market power could increase, which could lead to greater asymmetry (Borenstein, Cameron, and Gilbert 1997; Brown and Yücel 2000). Douglas and Herrera (2010) discuss the possibility of Reis's (2006) rational inattention on the parts of consumers leading to an increase in asymmetry for gasoline prices. Firms make more small upward changes in their price, which consumers do not bother to check if it is still the lowest price. In this case, the increased wholesale prices are exacerbated because a slightly larger change in price is now a smaller percentage change in price from the point of view of the consumers.

One specific example of the costs associated with being rationally inattentive is search costs. Davis (2007) found evidence of search costs having an impact on gasoline price asymmetry for retail stations. Tappata (2009) developed a model of search which showed that asymmetry should increase with production cost. During the RFG period production costs should be higher. We should therefore see higher asymmetry. Since the asymmetry could lead to higher prices than lower prices, the firms could see an increase in margins. The absence of a change in asymmetric pattern would not be conclusive of the lack of search costs, as other models of search would not suggest such an increase (Lewis 2011).

We therefore propose four possible explanations for the increased seasonality.

1. Increased cost of the gasoline that is produced. If the primary driver of the increased seasonality is cost increases then the cost increases should be almost exclusively seen by the stations under the RFG program.
2. Market segmentation and market power. If this explanation is the primary reason then the impact will be seen by both the RFG and non-RFG stations.
3. Switch over costs. If switch over costs are a significant portion of the cost, the impact should show up most dramatically in the spring and fall months.
4. Retail firms having higher prices because of rationally inattentive consumers. We would then expect to see two things. One would be an increased asymmetric pattern on the part of the firms. In particular firms could be increasing their prices more than decreasing them. Then, the firms that see the greatest increase in seasonality should be those that exhibit a change in asymmetric pattern. Second we would expect to see an increase in the margins of the retail stations.

III. METHODOLOGY

For this study we employ three methodologies.

A. OLS

For both the monthly national data and the daily individual stations, we test to see if there is any change in seasonality by regressing the price on monthly dummy variables, using the following regression:

$$\Delta P_t^G = \alpha + \gamma' X_t + \varepsilon_t \tag{1}$$

where P_t^G is the price of gasoline and X_t is a vector of seasonal dummies.

For the individual stations, we also examine the pattern of seasonality in the markup of retail prices over wholesale prices. For the national data series, we examine the pattern of seasonality of the oil prices to see whether the seasonal pattern is also exhibited upstream.

B. Error Correction Model

In trying to examine how much of the pattern is due to changes in the pattern in oil prices, we control for oil prices by using an ECM originally developed by Engle and Granger (1987). This approach used by Bachmeier and Griffin (2003) to examine the responses of gasoline prices(P_t^G) to oil prices (P_t^O)uses the following system of equations:

$$P_t^G = \alpha + \beta P_t^O + z_t \tag{2}$$

$$\begin{aligned} \Delta P_t^G = {} & \alpha + \beta_1 \Delta P_{t-1}^O + \beta_2 \Delta P_{t-2}^O + \beta_3 \Delta P_{t-1}^G \\ & + \beta_4 \Delta P_{t-2}^G + \theta z_{t-1} + \gamma' X_t + \varepsilon_t \end{aligned} \tag{3}$$

where the residual of the first equation (z_t) is used as an explanatory variable in the second equation.

The inclusion of monthly dummies (X_t) into the second equation was added by Davis (2009). We will use Davis's model but with a slightly different time span to see if the results still exist with the extended data set.

C. Logit

With monthly average data, the price is changing every day. With daily retail prices, there are many days on which the firms do not change prices. For these data, an ECM which assumes a constantly changing price would be inappropriate. For data of this type, Davis and Hamilton (2004) and Davis (2007) find that a logit model fits the data well. The logit is as follows:

$$\text{(4)} \qquad \Pr(y_i = 1|z_i, \beta) = \frac{e^{z_i'\beta}}{(1 + e^{z_i'\beta})}.$$

Specifically, we will test whether there is a change in behavior in the way that firms change their prices not under the RFG summer program and under the RFG summer program. We look at the response of the data to the gap between the actual gasoline price and the frictionless gasoline price, using the asymmetric approach of Davis and Hamilton (2004),

$$\text{(5)} \qquad \mathbf{z}_{it} = \Big[\theta_{it}, \theta_{it}(P_{i,t} - P^*_{i,t-m}), (1 - \theta_{it}), \\ -(1 - \theta_{it})(P_{i,t} - P^*_{i,t-m}), \\ \theta_{it} * RFGsummer, (1 - \theta_{it}) * RFGsummer\Big]'$$

where θ_{it} is a variable that is 1 if the gap between the price (P) and the frictionless price (P^*) is positive and 0 otherwise. A new inclusion in this model is the allowance for a difference in reaction to the RFG summer period, the months in 2000 and 2001 in which the RFG program is in force. m represents the number of days since the last observation. If the number of days since the last observation exceeds three, then it is not used in the analysis. The most likely days to be missed from the data collection are Saturdays and Sundays which are also probably the days least likely to see a price change. A 3-day gap seems a reasonable compromise to keep the Monday data in the data set.

The frictionless price is derived using the predicted values from the following regression:

$$\text{(6)} \qquad P_t^G = \alpha + \beta_1 P_1^W + \gamma' X_t + \delta * RFG \\ + \lambda' X_t * RFG + \varepsilon_t$$

where (P_t^G) is the retail station's price of gasoline, (P_t^W) is the wholesale price, X_t is a vector of dummy variables representing the months and *RFG* is a dummy variable that is 1 in the years that the RFG is in effect (2000 and 2001). This equation varies from that of Davis (2007) in that it includes seasonal effect in calculating the frictionless price. The change is necessitated by the findings of Davis (2009) and in the work here. One series of variables that might make sense to include in the price, the days of the week, has been shown not to be significant in the price of gasoline (Hall, Lawson, and Raymer 2007). However, Davis (2010) did show that these variables can significantly affect the probability of a price change, but we exclude the variables to keep the number of estimated parameters low given the small sample sizes.

IV. DATA

The gasoline prices for the entire United States are monthly average gasoline prices collected by the Energy Information Agency (EIA). The sample runs from 1976 to 2013. The oil prices are first purchase prices of crude oil, a monthly series also collected by the EIA.

The individual station gasoline prices were obtained from Oil Price Information Services (OPIS). The data contain individual stations' daily prices, including the wholesale price, the retail price, and the margin.

We are analyzing stations from six zip codes. The zip codes represent sections of six cities, Charleston, SC, Lansdale, PA, Scranton, PA, Norfolk, VA, Rolla, MO, and St. Louis, MO. Three of the areas would be subject to the requirements of the RFG program. Norfolk, VA and St. Louis, MO are subject to the standards of the RFG South program. Lansdale, PA, which is a suburb in the Philadelphia metropolitan area, is subject to the RFG North program. The other three cities are not subject to the RFG. The expensiveness of the data limits the analysis to these six cities, which is common in these types of studies (Davis 2007; Davis and Hamilton 2004; Douglas and Herrera 2010).

The six cities are not chosen at random, but selected for particular reasons. First, states with local regulations or the Oxygenated Gasoline (OXY) program are excluded to keep the effects specific to the RFG program. The OXY program is a similar program to the RFG gasoline program, but designed to provide more environmentally-friendly gasoline in the winter months as opposed to the summer months. Cities west of the Rocky Mountains are excluded as well because they tend to follow a different pattern of pricing relative to gas stations east of the Rockies. Charleston is selected because it represents one of the larger cities not effected by the RFG program. Norfolk is selected because it makes a nice parallel with Charleston but is subject to the RFG program. The Norfolk metropolitan area is larger than Charleston, but like Charleston it is a Southern port city. Another pair of cities is selected from Pennsylvania. Lansdale gives us a suburban city that is subject to the RFG regulation, while Scranton is a small city not subject to regulations. The last pair

TABLE 1
Description of Individual Stations' Retail Prices

Label	City	Brand	RFG	Number of Obs	Mean	Station Name	Mean not RFG	Mean RFG
Charleston 1	Charleston	BP	None	859	122.26	Pantry	113.20	140.51
Charleston 2	Charleston	Hess	None	798	119.79	Ashley River	110.88	138.13
Rolla 1	Rolla	Phillips 66	None	743	115.08	MPC50	105.82	140.20
Rolla 2	Rolla	Unbranded	None	794	118.27	Delano	108.20	141.36
Scranton 1	Scranton	BP	None	880	129.64	Unimarts	121.45	151.75
Scranton 2	Scranton	Sunoco	None	838	132.41	S7th	124.69	150.35
Scranton 3	Scranton	Sunoco	None	1,007	131.61	Stafford	123.37	152.10
Lansdale 1	Lansdale	Gulf	RFG North	833	127.88	North Penn	117.42	151.19
Norfolk 1	Norfolk	Texaco	RFG South	948	125.01	Suffolk	116.02	150.54
St. Louis 1	St. Louis	Shell	RFG South	726	126.32	Spirit	114.98	149.14

Source: Oil Price Information Services.

TABLE 2
Description of Individual Stations' Rack Prices

Label	City	Brand	RFG	Number of Obs	Mean	Station Name	Mean not RFG	Mean RFG
Charleston 1	Charleston	BP	None	859	73.38	Pantry	65.68	88.88
Charleston 2	Charleston	Hess	None	798	73.04	Ashley River	65.61	88.32
Rolla 1	Rolla	Phillips 66	None	743	73.36	MPC50	64.28	98.04
Rolla 2	Rolla	Unbranded	None	794	75.83	Delano	65.94	98.53
Scranton 1	Scranton	BP	None	880	70.17	Unimarts	62.86	89.91
Scranton 2	Scranton	Sunoco	None	838	73.53	S7th	66.76	89.27
Scranton 3	Scranton	Sunoco	None	1,007	71.39	Stafford	64.16	89.36
Lansdale 1	Lansdale	Gulf	RFG North	833	75.13	North Penn	65.84	95.84
Norfolk 1	Norfolk	Texaco	RFG South	948	72.47	Suffolk	63.61	97.61
St. Louis 1	St. Louis	Shell	RFG South	726	82.04	Spirit	70.10	106.07

Source: Oil Price Information Services.

comes from Missouri, where we have the small rural city of Rolla, not subject to RFG regulations, combined with St. Louis which is subject to the regulations. Both cities (and specifically the part of the city in St. Louis which is selected) are located along the same Intestate, I-44. Since the data is supplied by zip code, we chose zip codes that we hoped would have many gasoline stations in them.

The quality of the data is quite uneven. Many of the individual stations do not have a large number of observations. We restrict the sample to only those stations which have at least 694 observations, representing at least 2/3 of the weekdays during the four-year period. Table 1 provides summary statistics for the retail prices from the ten gasoline stations that are analyzed. Table 2 presents the same data for the rack prices that those stations pay for their gasoline. There is no apparent pattern relating the RFG program to the average price, which is to be expected. State and local factors, in particular taxes, will outweigh the importance of the RFG program when analyzing means. However, when comparing the prices during the RFG program months (the 2000 and 2001 summers) to the prices not during those periods, there does seem to be a difference in the change in prices. The non-RFG stations in Charleston and Scranton experience a smaller jump in both rack and retail prices than the RFG stations in Lansdale, Norfolk and St. Louis.

Interestingly, the Rolla stations exhibit a pattern similar to the RFG stations. One possibility is that Rolla is using the RFG gasoline obtained from wholesalers in St. Louis. Rolla is only 100 miles from St. Louis and is not large enough to have its own wholesalers. We examine the correlation coefficient between the Phillips 66-branded Rolla 1 station and two other Phillips 66-branded stations in St. Louis. The two St. Louis stations' wholesale rack prices are perfectly correlated. Rolla 1's rack prices have correlation coefficients of .982 and .994 with the two St. Louis stations. The lack of perfect correlation,

TABLE 3
Ordinary Least Squares Regressions for National Gasoline Average

	Δ Gas 1976–2013	Δ Gas 1976–1999	Δ Gas 2000–2013	Δ Oil 1976–2013	Δ Oil 1976–1999	Δ Oil 2000–2013
Constant	−3.666**	−0.896	−8.414**	−0.692	−0.295	−1.371
	(1.700)	(0.655)	(4.229)	(0.531)	(0.261)	(1.357)
January	4.925*	0.039	13.150**	1.130	0.266	2.579
	(2.420)	(0.936)	(5.980)	(0.756)	(0.373)	(1.918)
February	6.021**	0.183	16.029***	0.976	0.044	2.574
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
March	8.716***	0.242	23.243***	1.756**	0.073	4.641**
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
April	9.542***	3.450***	19.986***	1.552**	0.580	3.216*
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
May	8.334	3.367***	16.850***	0.841	0.413	1.576
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
June	4.292*	2.129**	8.000	0.912	0.152	2.215
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
July	2.550	0.596	5.900	1.419*	0.413	3.145
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
August	3.797	1.413	7.886	0.916	0.665*	1.345
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
September	4.376*	1.167	9.879	0.698	0.828**	0.474
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
October	−0.376	0.533	−1.936	0.300	0.681*	−0.353
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)
November	−1.124	0.483	−3.879	0.004	0.009	−0.005
	(2.404)	(0.926)	(5.980)	(0.751)	(0.369)	(1.918)

Notes: Standard errors in parentheses. The gasoline data are measured in cents per gallon and the oil data are in cents per barrel.
Source: Energy Information Agency.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.

while the two St. Louis stations have perfect correlation, leaves open whether the Rolla station is getting its wholesale gasoline from St. Louis.

There are obviously a number of missing days in each series. In order to determine whether a change in price took place, we examine the price relative to the price from the preceding observation. This process is different from the assumptions made by Davis (2007) when working with OPIS data.

V. RESULTS

A. National Gasoline Results

We re-estimate the models from Davis (2009) to examine whether adding nine more years of data changes the results with regard to the increase in seasonality. Table 3 presents the results of the regression equation using Equation (1) explained above. The three gasoline columns are broken into separate time periods: 1976–2013, 1976–1999 and 2000–2013. These time periods vary from Davis's trio of 1974–2004, 1974–1999 and 2000–2004.[1] The results show the same pattern with regard to increasing seasonality. The same regression is performed on oil prices. The results for those regressions can be found in columns 4–6. Again the results confirm Davis's earlier finding of greater seasonality in oil prices since 2000. Table 4 uses the error-correction framework shown in Equations (2) and (3). These results show that there is an increase in gasoline-price seasonality beyond what can be attributed to oil prices.

B. Individual Gasoline Station Results

Table 5 presents the results of unit root testing on the individual stations. Unit root testing is non-standard because of the missing data. The approach used here follows Ryan and Giles (1998) suggestion of interpolating the data by treating any missing observation as being the

[1] The difference in time periods relates to slight differences in the data available at the time from the Energy Information Agency.

TABLE 4
Error Correction Model for National Gasoline Average

	Δ Gas 1976–2013	**Δ Gas 1976–1999**	**Δ Gas 2000–2013**
Constant	−3.029**	−0.381	−8.707**
	(1.323)	(0.482)	(3.387)
ΔOil(−1)	1.610***	1.422***	1.534***
	(0.174)	(0.152)	(0.300)
ΔOil(−2)	0.304	−0.165	0.261
	(0.198)	(0.178)	(0.343)
ΔGas(−1)	0.169***	0.285***	0.114
	(0.057)	(0.066)	(0.100)
ΔGas (−2)	−0.307***	−0.198***	−0.295***
	(0.054)	(0.059)	(0.094)
Z(−1)	−0.049*	−0.015	−0.157**
	(0.025)	(0.012)	(0.070)
January	4.741**	0.198	11.539**
	(1.853)	(0.683)	(4.608)
February	3.382*	−0.350	10.091**
	(1.880)	(0.684)	(4.781)
March	7.423***	0.062	20.802***
	(1.881)	(0.675)	(4.834)
April	6.888***	3.218***	15.294***
	(1.897)	(0.673)	(5.009)
May	6.620***	1.541**	17.314***
	(1.904)	(0.708)	(4.985)
June	4.449**	1.315*	11.990**
	(1.911)	(0.704)	(4.991)
July	3.117	0.484	8.991*
	(1.892)	(0.698)	(4.857)
August	2.413	1.072	5.840
	(1.860)	(0.692)	(4.693)
September	2.875	−0.033	9.434**
	(1.852)	(0.676)	(4.694)
October	−1.054	−0.641	0.410
	(1.858)	(0.678)	(4.745)
November	−0.256	−0.343	1.029
	(1.851)	(0.673)	(4.658)

Notes: Standard errors in parentheses. The gasoline data are measured in cents per gallon.

Source: Energy Information Agency.

*Significant at 10%. **Significant at 5%. ***Significant at 1%.

TABLE 5
Unit Root Testing on Individual Stations Retail Prices

Station	***p* Value**
Lansdale 1	0.155
Norfolk 1	0.039
St. Louis 1	0.043
Scranton 1	0.083
Scranton 2	0.131
Scranton 3	0.250
Rolla 1	0.031
Rolla 2	0.038
Charleston 1	0.103
Charleston 2	0.156

Note: p values of Dickey-Fuller test with one lagged term and drift. *Source:* Oil Price Information Services.

same as the previous day's observation and then conducting the unit root test.

Five of the ten firms have *p* values below .1 and the other five firms have fairly low *p* values as well. The usual solution for unit roots of differencing the data is not a good solution here because of the missing data. Therefore, we proceed with the analysis using the data in levels.

For the individual stations we regress the retail price and the margin on monthly dummies and a constant to see if there is a seasonal pattern. We break up the sample into two time periods, before and after the RFG program is in place. First we examine the behavior of the prices (Tables 6–8). All of the stations show an increase in seasonality. The results do vary somewhat with regard to when the seasonality begins but in general all show prices peaking in the summer months.

The results for the margins are presented in Tables 9–11. Only three of the stations show an increase in the seasonality of gasoline price margins. Two of them are in areas in which the RFG program is in place. The station in Lansdale and the station in Norfolk show a significant pattern of seasonality in the price margin in the later sample. Amongst the non-RFG affected areas, only Rolla 2 shows an increase in seasonality in the margin and it is not as dramatic as for the two RFG affected areas. The rest of the stations in Charleston, Rolla and Scranton do not show much of a change in seasonality in the margins. The St. Louis station, unlike the other RFG affected stations does not show an increase in seasonality.

After estimating the logit model of Equations (4–6), the probability of a change is calculated for price differences between −20 and + 20 cents. Since the price differences represent the actual minus the expected, a negative value implies a likely price increase, while a positive value implies a price decrease. In Figures 2–4, we present the findings for each station side-by-side. The results show a pretty mixed picture with some firms exhibiting the standard asymmetry of raising their prices faster than they lower them. Some stations exhibit a reverse asymmetry, being more likely to make small upward changes and large downward changes. This result is usually explained by assuming that firms are worried about upsetting their customers (see Davis 2007; Davis and Hamilton 2004;

TABLE 6
OLS Regressions for Individual Stations' Prices (RFG Stations)

	Lansdale 1 (98 & 99)	Norfolk 1 (98 & 99)	St. Louis 1 (98 & 99)	Lansdale 1 (00 & 01)	Norfolk 1 (00 & 01)	St. Louis 1 (00 & 01)
Constant	113.11	112.80	102.60	117.71	119.18	116.57
	(1.707)	(1.509)	(1.987)	(1.762)	(1.871)	(1.978)
January	−12.582	−11.125	−17.367	20.631	16.843	18.507
	(2.536)	(2.207)	(3.804)	(2.654)	(2.629)	(3.002)
February	−17.034	−17.539	−17.008	18.983	18.789	20.650
	(2.414)	(2.259)	(4.011)	(2.619)	(2.598)	(2.909)
March	−20.243	−16.780	−13.700	22.169	26.801	25.141
	(2.435)	(2.134)	(3.637)	(2.619)	(2.801)	(2.888)
April	−13.064	−10.543	3.800	27.679	34.881	36.799
	(2.435)	(2.161)	(3.716)	(2.692)	(2.583)	(2.888)
May	−8.624	−7.632	1.967	40.926	38.809	44.069
	(2.536)	(2.191)	(7.521)	(2.587)	(2.569)	(2.869)
June	−6.957	−6.952	5.217	45.256	38.456	37.416
	(2.435)	(2.147)	(4.135)	(2.558)	(2.598)	(2.782)
July	−7.207	−5.246	4.100	39.166	28.437	19.538
	(2.599)	(2.279)	(3.034)	(2.712)	(2.786)	(3.002)
August	−1.249	−2.073	1.019	25.746	23.286	23.602
	(2.536)	(2.134)	(2.980)	(2.558)	(2.569)	(2.738)
September	0.085	−4.327	4.670	21.264	23.527	33.276
	(2.536)	(2.260)	(3.129)	(2.636)	(2.598)	(2.850)
October	0.524	−2.508	0.559	14.575	15.588	12.516
	(2.482)	(2.176)	(3.129)	(2.558)	(2.543)	(2.814)
November	−4.278	−4.109	−4.644	5.703	8.044	5.659
	(2.991)	(2.344)	(3.566)	(2.530)	(2.543)	(2.814)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

TABLE 7
OLS Regressions for Individual Stations' Prices (Scranton Stations)

	Scranton 1 (98 & 99)	Scranton 2 (98 & 99)	Scranton 3 (98 & 99)	Scranton 1 (00 & 01)	Scranton 2 (00 & 01)	Scranton 3 (00 & 01)
Constant	115.11	117.93	120.36	134.85	132.36	135.57
	(1.583)	(1.858)	(1.536)	(1.617)	(1.455)	(1.257)
January	−7.339	−21.780	−12.457	8.489	13.167	10.042
	(2.312)	(3.598)	(2.241)	(2.272)	(2.145)	(1.884)
February	−13.839	−24.197	−19.582	8.223	12.048	8.009
	(2.312)	(3.127)	(2.222)	(2.244)	(2.158)	(1.906)
March	−14.634	−23.830	−20.241	12.140	15.047	12.975
	(2.222)	(3.024)	(2.142)	(2.185)	(2.087)	(1.863)
April	−9.261	−10.266	−14.931	15.101	17.229	13.995
	(2.207)	(3.186)	(2.128)	(2.244)	(2.247)	(1.895)
May	−5.794	−7.173	−10.743	19.077	23.466	18.536
	(2.239)	(2.979)	(2.172)	(2.244)	(2.199)	(1.895)
June	−5.692	−7.767	−10.432	21.842	23.204	21.578
	(2.193)	(3.074)	(2.103)	(2.287)	(2.199)	(1.895)
July	−5.496	−11.471	−9.686	17.295	17.142	20.284
	(2.292)	(2.608)	(2.172)	(2.372)	(2.185)	(1.918)
August	−2.331	−6.413	−8.222	12.119	11.495	11.196
	(2.153)	(2.608)	(2.187)	(2.196)	(2.121)	(1.844)
September	−2.206	−6.063	−8.393	16.903	16.090	14.176
	(2.292)	(2.669)	(2.241)	(2.258)	(2.264)	(1.918)
October	−2.071	−5.447	−7.720	8.153	11.211	7.668
	(2.193)	(2.572)	(2.128)	(2.258)	(2.185)	(1.873)
November	−5.380	−7.430	−9.057	3.053	5.580	1.981
	(2.492)	(2.830)	(2.379)	(2.258)	(2.133)	(1.884)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

TABLE 8
OLS Regressions for Individual Stations' Prices (Charleston & Rolla Stations)

	Rolla 1 (98 & 99)	Rolla 2 (98 & 99)	Char. 1 (98 & 99)	Char. 2 (98 & 99)	Rolla 1 (00 & 01)	Rolla 2 (00 & 01)	Char. 1 (00 & 01)	Char. 2 (00 & 01)
Constant	93.275	95.32	102.53	100.01	112.56	109.39	119.99	117.02
	(1.709)	(1.707)	(1.560)	(1.843)	(2.362)	(2.133)	(1.546)	(1.603)
January	−4.513	−17.554	−19.063	−18.907	11.720	16.179	10.168	10.189
	(2.636)	(3.209)	(3.092)	(3.121)	(3.103)	(2.914)	(2.279)	(2.317)
February	−7.981	−18.737	−20.190	−20.261	16.156	20.466	13.125	15.403
	(2.542)	(2.957)	(2.824)	(3.274)	(3.155)	(2.945)	(2.279)	(2.391)
March	−7.875	−14.725	−15.907	−16.238	20.295	22.769	18.199	18.686
	(2.521)	(2.780)	(2.640)	(2.745)	(3.102)	(2.945)	(2.253)	(2.291)
April	0.730	5.329	−1.884	−4.869	19.442	26.684	26.081	26.044
	(3.012)	(2.907)	(2.724)	(2.816)	(3.287)	(2.979)	(2.279)	(2.463)
May	7.125	5.722	−2.034	−3.274	35.315	41.436	29.186	31.103
	(3.558)	(2.861)	(2.824)	(3.366)	(3.216)	(3.016)	(2.321)	(2.391)
June	3.773	5.779	−2.034	−6.107	42.087	44.037	25.663	25.982
	(2.692)	(3.740)	(2.724)	(2.999)	(3.287)	(2.962)	(2.293)	(2.278)
July	5.219	2.095	−2.664	−6.403	16.724	20.243	14.741	14.530
	(2.564)	(2.547)	(2.336)	(2.631)	(3.341)	(3.057)	(2.253)	(2.303)
August	2.883	2.023	−3.180	−3.569	18.704	23.308	12.352	13.082
	(2.586)	(2.448)	(2.336)	(2.657)	(3.120)	(2.929)	(2.186)	(2.330)
September	6.589	7.579	−4.051	−5.107	33.484	36.092	17.622	17.814
	(2.663)	(2.621)	(2.567)	(2.563)	(3.175)	(3.036)	(2.241)	(2.291)
October	2.366	5.758	0.580	−1.137	17.860	22.297	16.232	10.112
	(2.692)	(2.399)	(2.449)	(2.489)	(3.238)	(3.057)	(2.424)	(2.291)
November	−3.232	2.544	−3.253	−2.695	10.377	8.243	0.613	3.334
	(2.913)	(2.595)	(2.680)	(2.999)	(3.387)	(3.057)	(2.218)	(1.603)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

TABLE 9
OLS Regressions for Individual Stations' Margins (RFG Stations)

	Lansdale 1 (98 & 99)	Norfolk 1 (98 & 99)	St. Louis 1 (98 & 99)	Lansdale 1 (00 & 01)	Norfolk 1 (00 & 01)	St. Louis 1 (00 & 01)
Constant	8.229	20.189	10.699	3.215	11.693	11.467
	(0.690)	(0.635)	(0.707)	(0.930)	(0.939)	(0.986)
January	−2.027	−3.471	−0.654	3.626	1.037	−3.776
	(1.026)	(0.929)	(1.354)	(1.401)	(1.320)	(1.496)
February	−1.380	−6.039	2.004	−0.352	−1.960	−4.361
	(0.976)	(0.951)	(1.427)	(1.383)	(1.305)	(1.449)
March	−7.064	−9.378	−4.754	1.482	2.431	−1.759
	(0.985)	(0.898)	(1.294)	(1.383)	(1.265)	(1.439)
April	−6.698	−9.823	2.083	−0.904	3.633	2.829
	(0.985)	(0.910)	(1.322)	(1.421)	(1.297)	(1.439)
May	−3.574	−7.605	−2.747	0.515	1.733	−5.975
	(1.026)	(0.922)	(2.676)	(1.366)	(1.290)	(1.429)
June	−0.546	−5.248	−0.738	10.994	6.890	−1.257
	(0.985)	(0.904)	(1.471)	(1.350)	(1.305)	(1.386)
July	−2.900	−5.126	−0.892	20.929	7.335	5.155
	(1.051)	(0.959)	(1.080)	(1.432)	(1.399)	(1.496)
August	−1.725	−3.594	−2.332	4.683	0.197	−1.914
	(1.026)	(0.898)	(1.060)	(1.350)	(1.290)	(1.364)
September	−2.891	−4.896	−0.475	−0.738	0.813	0.349
	(1.026)	(0.951)	(1.114)	(1.392)	(1.305)	(1.420)
October	−0.371	−4.229	−0.373	4.783	5.562	−1.379
	(1.004)	(0.916)	(1.114)	(1.350)	(1.277)	(1.402)
November	1.165	−0.666	3.026	−0.218	1.497	−3.490
	(1.210)	(0.987)	(1.269)	(1.336)	(1.277)	(1.402)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

TABLE 10
OLS Regressions for Individual Stations' Margins (Scranton Stations)

	Scranton 1 (98 & 99)	Scranton 2 (98 & 99)	Scranton 3 (98 & 99)	Scranton 1 (00 & 01)	Scranton 2 (00 & 01)	Scranton 3 (00 & 01)
Constant	15.714	11.974	15.786	18.283	16.301	19.468
	(0.643)	(0.365)	(0.509)	(0.897)	(0.669)	(0.844)
January	0.212	0.352	−0.445	−3.647	−0.718	−3.975
	(0.939)	(0.706)	(0.742)	(1.260)	(0.986)	(1.265)
February	−2.927	0.161	−2.310	−7.810	−4.861	−9.134
	(0.939)	(0.614)	(0.736)	(1.245)	(0.992)	(1.280)
March	−6.225	−6.140	−6.329	−5.757	−3.734	−5.850
	(0.903)	(0.594)	(0.710)	(1.212)	(0.960)	(1.251)
April	−7.469	−3.796	−8.002	−6.353	−3.812	−8.320
	(0.896)	(0.625)	(0.705)	(1.245)	(1.033)	(1.273)
May	−5.761	−1.564	−5.341	−8.917	−5.316	−10.534
	(0.909)	(0.585)	(0.719)	(1.245)	(1.011)	(1.273)
June	−4.006	−1.144	−3.228	−0.931	0.571	−0.556
	(0.891)	(0.603)	(0.697)	(1.268)	(1.011)	(1.273)
July	−5.854	−5.773	−5.191	6.677	6.002	9.760
	(0.931)	(0.512)	(0.719)	(1.315)	(1.005)	(1.288)
August	−5.875	−4.237	−7.432	−2.573	−3.077	−2.999
	(0.874)	(0.512)	(0.725)	(1.218)	(0.975)	(1.238)
September	−7.131	−5.223	−8.938	−2.713	−4.222	−5.471
	(0.931)	(0.524)	(0.742)	(1.252)	(1.041)	(1.288)
October	−7.429	−3.383	−7.618	−0.642	−0.247	−1.654
	(0.891)	(0.505)	(0.705)	(1.252)	(1.005)	(1.258)
November	−4.358	−0.651	−3.662	−4.010	−2.686	−3.587
	(1.012)	(0.555)	(0.788)	(1.252)	(0.980)	(1.265)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

TABLE 11
OLS Regressions for Individual Stations' Margins (Charleston & Rolla Stations)

	Rolla 1 (98 & 99)	Rolla 2 (98 & 99)	Char. 1 (98 & 99)	Char. 2 (98 & 99)	Rolla 1 (00 & 01)	Rolla 2 (00 & 01)	Char. 1 (00 & 01)	Char. 2 (00 & 01)
Constant	4.896	5.721	12.579	10.830	5.353	4.539	15.658	14.649
	(0.767)	(0.617)	(0.405)	(0.466)	(1.067)	(0.989)	(0.848)	(0.933)
January	1.503	−3.343	−4.649	−3.976	−2.124	−0.990	−6.682	−10.056
	(1.183)	(1.160)	(0.802)	(0.789)	(1.401)	(1.351)	(1.250)	(1.348)
February	−1.016	−3.943	−3.965	−4.708	−4.158	−2.329	−8.300	−7.091
	(1.141)	(1.069)	(0.733)	(0.828)	(1.425)	(1.365)	(1.250)	(1.391)
March	−4.921	−10.853	−9.135	−9.179	−0.256	0.359	−1.880	−2.525
	(1.131)	(1.005)	(0.685)	(0.694)	(1.401)	(1.365)	(1.236)	(1.333)
April	−1.055	1.305	−4.826	−6.671	−0.735	−0.621	1.610	−0.684
	(1.351)	(1.051)	(0.707)	(0.712)	(1.484)	(1.381)	(1.250)	(1.433)
May	3.299	3.391	0.058	−5.704	−2.717	−0.629	−1.750	−2.718
	(1.597)	(1.034)	(0.733)	(0.851)	(1.452)	(1.398)	(1.273)	(1.391)
June	1.857	4.004	−2.757	−6.335	4.944	7.928	2.274	1.925
	(1.208)	(1.352)	(0.707)	(0.758)	(1.484)	(1.373)	(1.257)	(1.326)
July	−0.176	−2.159	−4.308	−6.464	2.424	3.916	2.379	1.620
	(1.150)	(0.920)	(0.606)	(0.665)	(1.508)	(1.417)	(1.236)	(1.431)
August	−1.687	−2.236	−4.752	−5.614	−5.933	−5.915	−4.335	−4.965
	(1.161)	(0.885)	(0.606)	(0.672)	(1.408)	(1.358)	(1.199)	(1.356)
September	0.095	−0.180	−6.643	−6.841	0.864	2.124	−3.578	−4.301
	(1.195)	(0.947)	(0.666)	(0.629)	(1.433)	(1.408)	(1.229)	(1.333)
October	−0.205	3.603	−1.242	−2.411	−0.493	3.522	2.844	1.465
	(1.208)	(0.867)	(0.636)	(0.758)	(1.462)	(1.417)	(1.330)	(1.333)
November	1.271	5.948	2.798	−0.166	−1.299	−0.985	−4.968	−4.120
	(1.307)	(0.938)	(0.696)	(0.466)	(1.484)	(1.417)	(1.216)	(1.431)

Note: Standard errors in parentheses.
Source: Oil Price Information Services.

Douglas and Herrera 2010). When comparing the RFG periods to the non-RFG periods, most of the firms moved toward greater likelihood of raising prices than lowering them, including Lansdale, Norfolk, Charleston 1 and all three Scranton stations.

VI. DISCUSSION

We support previous findings that there has been an increase in seasonality in gasoline prices. The results from the individual gasoline stations also suggest that the seasonality is much more prevalent in 2000 and 2001 than in 1998 and 1999, supporting the contention that Phase II of the RFG program increased the seasonal variation in gasoline prices.

Wholesale price increases seem to be the primary cause for the retail price increases, as many of the firms increase their prices, but do not increase their margins during the summer. There is evidence in support of the cost increase story at the wholesale level as the RFG firms experience the greatest increase in their wholesale price. However, all of the firms exhibit an increase in their wholesale prices as shown by the increase in the retail prices much more than the increases in the margins. Therefore, there is also evidence in support of the market power explanation since the non-RFG stations are not required to sell a specific gasoline in the summer and should only see prices rise due to market segmentation.

There are some interesting results at the retail level as suggested by the price margins. Two firms increased their margins, but at the same time increased their probability of making upward changes relative to downward ones. Since these two stations are RFG stations, there is some support for the rational inattention of consumer theory. Since they are the stations selling the more expensive gasoline, the RFG stations would be the ones most likely to fit the criteria of the Tappata (2009) model. St. Louis, the third RFG station, however, clearly does not support this pattern. It does not show an increased seasonality in margins and actually shows a greater likelihood of lowering prices during the RFG years than the earlier years.

There may be some support to the switch-over theory at least as it relates to the spring change. While the fall-switching month of October is not very large in its seasonal coefficient, the spring-switching month of April has one of the largest month coefficients for both the national data and the individual RFG station data. Also March has the highest prices of the non-RFG months, so the stations may be raising prices as they run down supplies in anticipation of having to switch to the RFG-compliant gasoline. Lastly we might expect that the switchover costs would be higher for the spring than the fall, since the stations can continue to sell the higher-quality gasoline even in the winter. They have to switch in the spring; they do not have to switch in the fall.

The overall results point to increased costs as at least as one of the primary causes. The impact on seasonality seems to come in most clearly through the wholesale prices, and the jump in seasonality is strongest with the RFG stations. The Rolla stations exhibit stronger seasonality than the other non-RFG locations and the Rolla stations are the ones most likely would be getting their gasoline from an RFG wholesaler given their proximity to St. Louis.

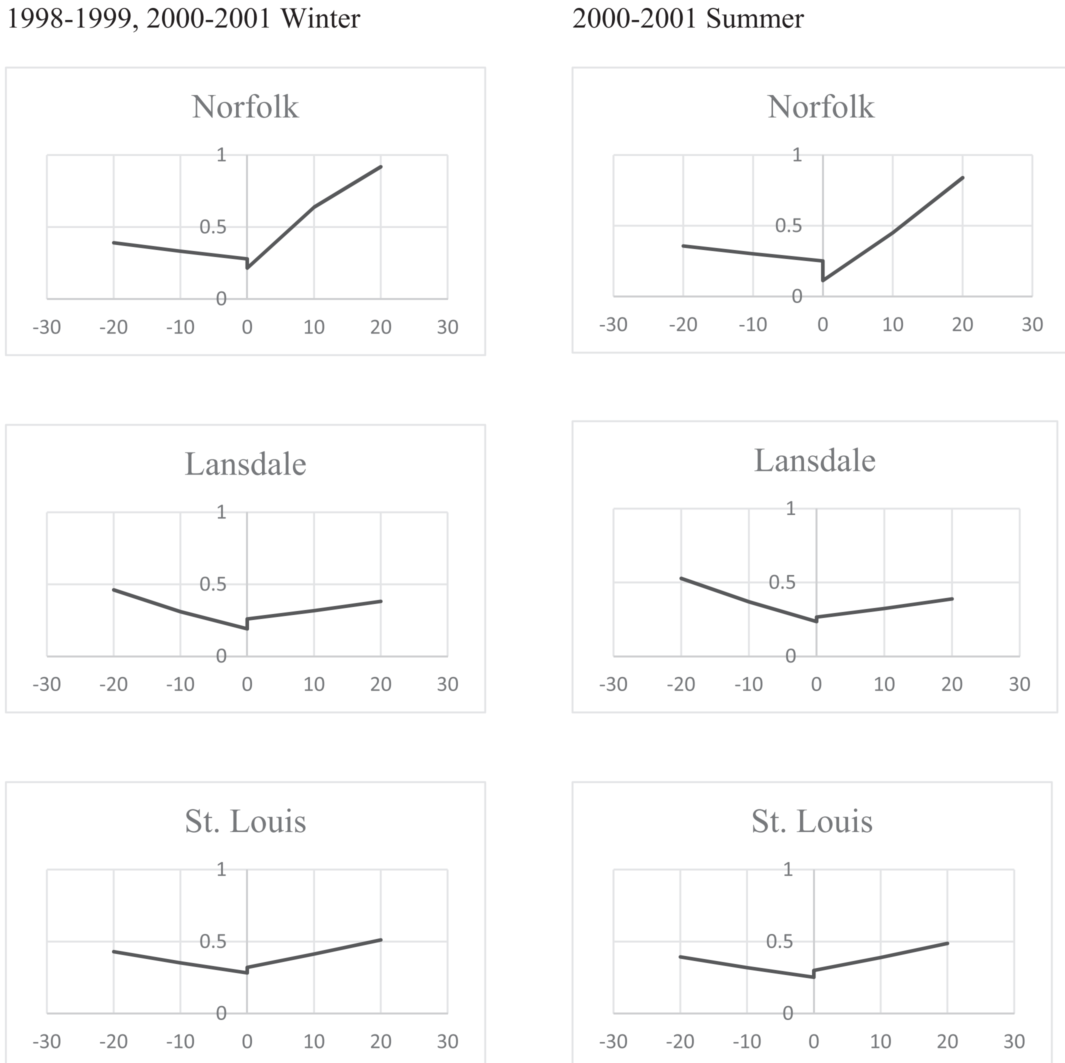
While the evidence does seem to support the idea of increased seasonality, it does not prove that the cause of that increased seasonality is from environmental regulations. Davis (2007) discusses two other possible causes of the increased seasonality, natural gasoline price increases and increased driving due to 9/11. The paper rejects both alternative hypotheses. The natural gasoline explanation is based on the idea that there was a price spike in natural gasoline prices in 2000. However, Serletis and Rangel-Ruiz (2004) show that there is little connection between natural gasoline and crude oil. Davis (2007) also rejects the driving hypothesis because while air travel increased, car travel did not change dramatically following 9/11. Also the pattern still remains many years later despite the impact of 9/11 on traveling having dissipated.

Other long-term impacts on gasoline such as ride sharing or alternative-fuel vehicles could influence gasoline prices. However, those impacts would be long-term changes and would not have any short-term influence as exhibited in 2000 and 2001 relative to 1998 and 1999. Also while likely influencing gasoline prices in general, those impacts would not have an obvious impact on seasonal prices.

VII. CONCLUSION

We find support for increasing seasonality of gasoline prices following the imposition of the RFG Phase II program. We find some evidence

FIGURE 2
Probabilities of Price Changes

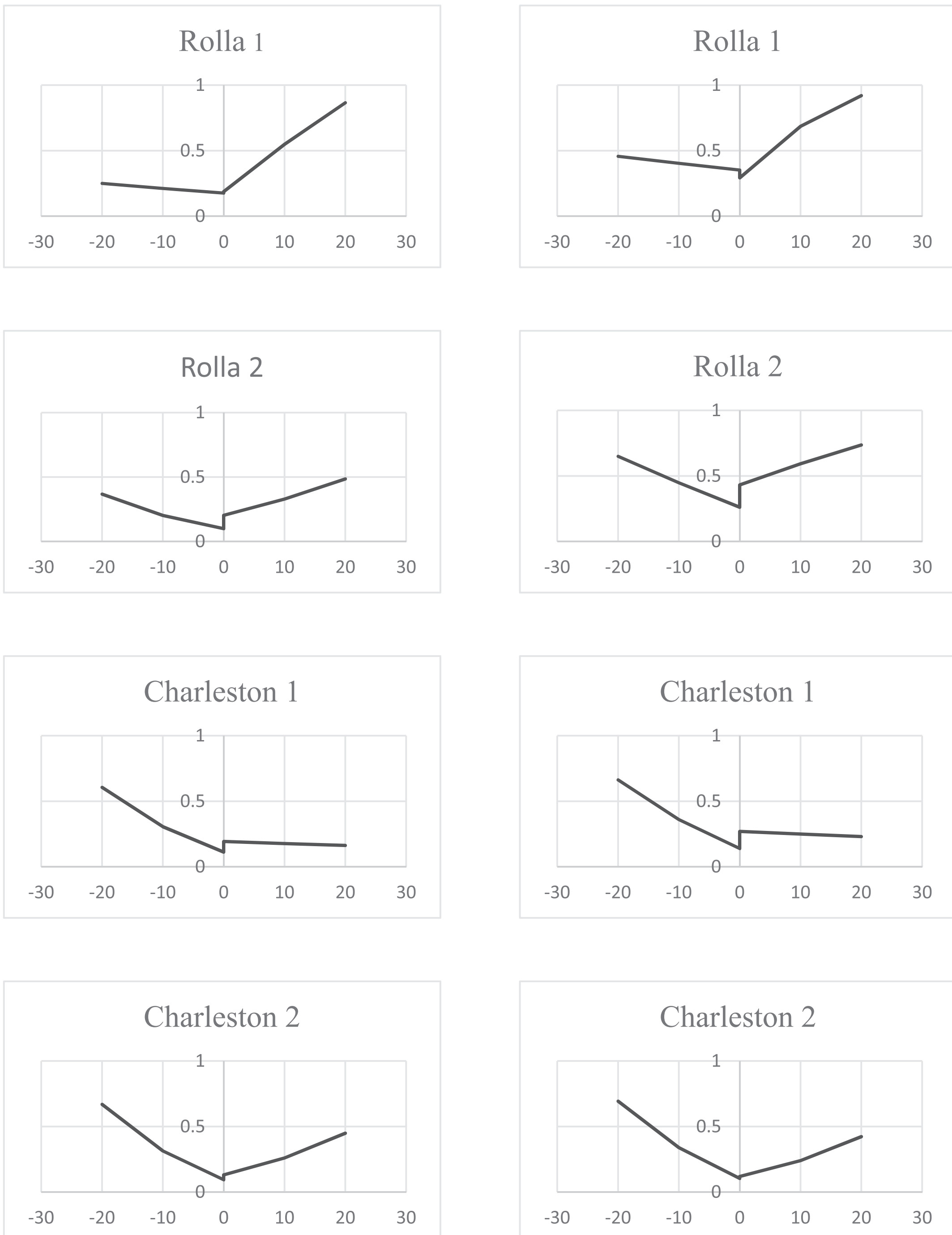


Data: Oil Price Information Services

supporting both the increasing costs of producing RFG gasoline and increasing market power of retailers through increases in wholesale gasoline prices. There also seems to be a substantial change in price dynamics at the retail level, but not one with a notable pattern across stations. Two stations seem to have evidence supporting the theory that the asymmetry increased during the RFG period and showed a substantial increase in its markup over wholesale prices. However, the third RFG station showed opposite results. Therefore we find mixed results in support of prices being higher due to firms charging higher prices due to search costs changing. Lastly we also find mixed support for the explanation of switch-over costs, as prices are higher in March and April but not in September and October.

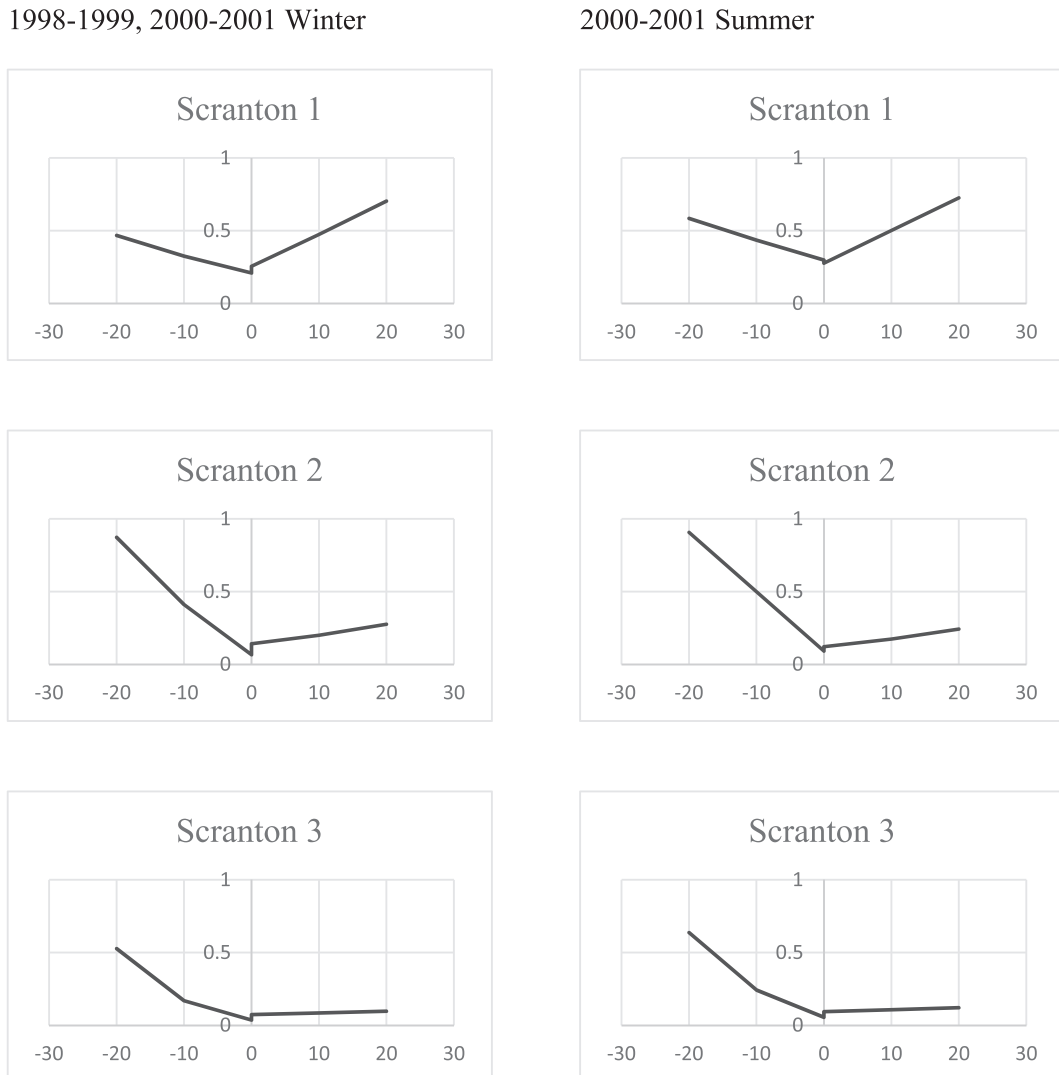
FIGURE 3
Probabilities of Price Changes

1998-1999, 2000-2001 Winter 2000-2001 Summer



Data: Oil Price Information Services

FIGURE 4
Probabilities of Price Changes



Data: Oil Price Information Services

The impact of the seasonality leads to higher prices for consumers. The margins for the summer gasoline during the RFG program are higher than the margins during the periods when the RFG program is not in effect, whether that is the winters after 2000 or any time before 2000. However, the higher prices may be efficient as presumably the program was put in place because the environmental impacts are more severe during the summer. The increased costs may be helping to reflect the true social cost of driving in summer relative to winter.

Future work should attempt to expand the analysis of the impact on prices to other environmental regulations. This study specifically picked locations that had neither individual state regulations nor the OXY program in place, but those regulations might impact seasonality as well. In particular the impact of the OXY program would be a natural extension since that program places stricter regulations in the winter months.

APPENDIX: DATA SOURCES

Monthly United States Gasoline Prices: Energy Information Agency.

Monthly United States Crude Oil Prices: Energy Information Agency.

Individual Station Daily Retail Prices: Oil Price Information Services.

Individual Station Daily Rack Prices: Oil Price Information Services.

Individual Station Daily Margins: Oil Price Information Services.

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